OVERCOMING THE COMPLEX PROBLEM SOLVING: THE ROLE OF SYSTEMS THINKING

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ABSTRACT

To seek the solution of a complex problem without systemic thinking becomes incoherent with the nature of the problem. Sustainability problems are multifaceted, ambiguous and complex. Solving these problems will depend on the capacity to find innovative solutions and simultaneously fulfill stakeholder needs. Public managers play an important role in solving sustainability problems, understanding their complex context and planning long-term strategies. Systemic thinking can be stimulated by social experiences, which increase the level of consciousness and empathy of the decision maker. As one of today's greatest challenges, sustainability requires that the systemic thinking can be built as an individual dynamic capability that will enable the effective problem solution. We propose a new form of dealing with sustainability complex problem solutions, by using field experiments based on neural tests and Systemic Assistance Methodology (SAM). We expect to measure the level of systemic thinking of public managers in sustainability problem solving.

Keywords: Systems thinking; Sustainability; Complexity; Problem-solving; Research Method.

1. Overview

Organizations are currently being pressured both externally (Wolf, 2014; Fernandez-Feijoo, Romero & Ruiz, 2014) and internally (Collins, Roper & Lawrence, 2010) for superior sustainability results. This challenge is unanimous for any type of company, size, sector, origin of capital or technological level. Also, the public sector has a fundamental role in creating strategies for the sustainability of society. Even knowing that stakeholders must work collaboratively to deal with the problem of sustainability (Freeman, 1994), always complex, it is still the public management that has the legal attribution of planning and implementing sustainability actions in society.

Sustainability, when defined as the efforts of the current generation to secure the survival resources of future generations (Brundtland, 1987) may seem like a simple activity. However, the problems arising from this context are multifaceted, simultaneous and ambiguous, or as we may understand are a complex problem (Morin & Lisboa, 2007; Cohen & Axelrod, 2000; Beautement & Broenner, 2010)

The challenge of solving complex problems is beyond the choice of method, it remains in the environment dynamics. Linear responses are innocuous since consistent adaptations are inserted into diffuse and discontinuous perceptions and cannot be understood and treated in its totality. In Bertalanffy (1975) works of the 1930s, only emphasized in the 1950s, systems are composed of interacting parts. Open systems contemplate the relation with the surroundings seeking a balance for survival, through dynamic adaptations. Even deliberate actions, even those of intervention, are dependent on the system context, from which they are produced (Neves and Neves, 2006) which, in turn, depends on the system functioning itself. It begins with an understanding of a solution that seeks the requisite variety (Asby, 1991) necessary for the recursive process of self-organization and adaptation of its actors and resources, reacting to changing from the context.

Complex problems solution walks towards deliberate learning (Zollo & Winter, 2002) when organizations execute the interactions as processes of innovation and learning intending to solve complex problems (Cadwallader, 1959). The organization's ability to develop behavior and learning aligned to solving its problems and strategy for the future is also the result of a system/environment complex interface.

Sustainability problem solving will depend on the capacity to find innovative solutions that address global issues and, simultaneously, fulfill stakeholder needs (Esty et al., 2006). However, the first step involves changing perspectives to enable a view of the world and its complex problems through a systemic and integrated point of view (Mebratu, 1998). This vision allows for flexible ideas because it is based on a multidisciplinary approach that seeks to establish a dynamic and harmonious balance through the combination of the natural and behavioral sciences (Belico & Silveira, 2000). Thinking about complexity it is possible to comprehend the sustainability paradigm and to understand that a real action towards sustainable practices has to pass through, necessarily, changes and adaptations, so to become a capability, able to readapt dynamically over time. A capability is considered dynamic when it enhances the ability to make decisions, solve problems, identify opportunities and threats, and modify existing resources (Barreto, 2009).

Academics have sought to understand complex problem-solving situations in a variety of ways. By computational simulations for decision making and scenario creation (Dörne & Reither, 1978), by psychological characteristics (Frensch & Funke, 2014), knowledge intensity in the task and cognitive flexibility (Krems, 1995), by leadership skills (Mumford et al., 2000), by managerial principles and mechanisms (Sternberg & Frensch, 2014) and more recently by artificial intelligence (Russell & Norvig, 2016). Solving sustainability problems, with its complex nature, has required efforts to make the decision-making process more effective.

To seek the solution of a complex social problem without the systemic vision and only with a linear vision becomes incoherent with the nature of the problem. As one of the great challenges of the third millennium, the problem of sustainability appears all the time in the business environment and public management. How to solve these problems effectively if there is no systemic thinking that allows a complete perception of the problem and involves more variety in its solution?

Systemic social experiences can stimulate the collaborative problem solution, by changing perspectives and enhancing the systems thinking (Vasconcelos, 2015). These experiences, as social interactions, can increase the level of consciousness and empathy and promote greater involvement and systemicity in solving problems (Singer & Lamm, 2009; Gerdes et al., 2011).

We propose a new form of dealing with sustainability complex problem solutions. Using field experiments based on neural tests and Systemic Assistance Methodology (SAM) (Vasconcelos, 2015) we intend to measure the level of systemic thinking of public managers in the problem-solving of sustainability context.

2. Theory development

There has been a growing interest in finding new ways of understanding sustainability from a holistic point of view (Espinosa & Porter, 2011). One of these approaches is following ideas from complexity theory to social systems (Perrow, 1972). Sustainability can be considered a complex problem if we take its conceptual approach as a large number of interdependent parts that together display properties that would not be obvious from an examination of the individual parts (Bertalanffy, 1975; Byrne, 2002). Global awareness for sustainable development has made this issue even more challenging, bringing together responsibilities with multiple stakeholders in a relatively long-term objective.

The public manager is a key element on sustainability problem-solving. Due to the relevant capacity of changing society, the public manager can contribute to sustainable performance in all its dimensions, environmental, economic, social and cultural. She/he represents the actual public deciders (Pollitt, 2003) and much of the consequences of the availability of resources in the future is directly related to their critical planning process (Mazzara et. al., 2010).

The decision criteria and the priority understanding of public policies are related to what this public manager, *ceteris paribus*, thinks will be critical or wicked (Head & Alford, 2015) to the future development of a locality or, the incentives (Green & Laffont, 1979) he believes will have payback.

Developing new problem-solving methods can be a possible way to minimize judgments and equivocate public decision. Systems thinking is being used to problem-solving in private companies in a more consistent way (Sternberg, 2014; Mumford et. al., 2000) but when it comes to public sector studies are normally case studies of cybernetics frameworks such Viable System Model (VSM) or Soft Systems Methodology (SSM). Although the limited scope of applications, systems thinking presents powerful unfoldings offering important contributions to sustainability

studies as a whole, especially in theoretical fundamentals of concepts such as self-organization (Kauffman, 1996), emergence (Keating, 2008) co-evolution (Dors & Cross, 2001) and viability (Beer, 1979) applied to learning organizational processes (Senge, 1990).

Several studies have been pointing to the benefits of systems thinking on mental models or mindsets (Werhane, 2008, Assaraf & Orion, 2005, Ben-Zvi-Assaraf & Orion, 2010) and pursuing different methods for developing cognitive competences (Boyatzis, 2006). The results point to empathy or emotional involvement (Decety & Ickes, 2011, Shamay-Tsoory, Aharon-Peretz & Perry, 2009) and consciousness (Revonsuo, 2006) as moderators to experimental research designs (Bion, 1962).

Systems thinking states that learning is the critical process for a system homeostasis, providing environmental adaptation and contributing for its surviving in changing contexts (Senge Sterman, 1992). On the other hand, dynamic capabilities theory develops as an approach that explains the consistent performance - competitive advantage - of organizations in highly complex environments and constant change by the ability to relatively create and recombine resources in new ways (Helfat & Peteraf, 2009).

Strongly rooted in evolutionary economics and resource-based view, dynamic capabilities theory presents itself to this challenge by arguing that it is feasible for organizations in dynamic environments to consistently create and recombine resources in new ways (Eisenhardt & Martin, 2000; Helfat & Peteraf, 2009; Teece, Pisano & Shuen, 1997). An organization or individual can achieve multiple possibilities of learning and change their decision-making structure and criteria when incorporates systems thinking. Other important question, highlighted by Zollo, Cennamo and Neumann (2013), is the adaptive capacity to respond to pressures to innovate and change toward sustainable enterprise models.

By thinking as a whole, considering multiple stakeholders, understanding implications of phenomena in different levels of recursion and for different stakeholders, we believe that better, broader and long-term decision will be made. In this sense, can public managers perform better or have more effective decision by its level of systemic thinking?

Hereupon, the notion of systems thinking can be considered as a source of individual dynamic capability to public managers and improve his(her) decisions in complex situations of sustainability problems.

3. Methodology

As discussed above, sustainability is a complex problem, demanding an effective solution. Social systemic experiences can be a trigger to promote this systemic thinking. We use SAM (Vasconcellos, 2015) as a field experiment to co-construct solutions to a sustainability problem situation.

To Vasconcellos (2015) the co-construction of solutions to a problem-situation process occurs through the creation of a collaborative context of autonomy, relating to the shared knowledge to more systemic solutions, where different stakeholders can solve problems together through a dynamic conversation session.

Specialists as psychologists, doctors, managers can influence and take decisions about problem-solving but only stakeholders consensus can bring legitimacy to complex problem-solution. (VASCONCELLOS, 2015).

This methodology aims to two fundamentals aspects: the form of constitution of the "problem-determined system" (PDS) and the form of coordination of conversations of the PDS.

The problem-determined system (PDS) consist of a complex problem (Bar-Yam, 1997), involving multiple stakeholders (Freeman, 1994). The first assumptions about the solution for the problem

are designed in stakeholders identification and conversations among them. This process can be developed by Delphi Method (Cezarino, 2013), focus group (Kitzinger, 1995) or any technique that stimulate interactions between stakeholders, avoiding multiple interviews or isolated data collection from each source.

3.1 Experimental Design

In this sense, according to Vasconcellos (2015), we will use a complex sustainability problem in a Brazilian city as PDS and SAM to promote conversations and systemic thinking in the problem solution.

A group of public managers will be invited to take part in an experiment. They will sit together in a room, where they will attend to a short presentation - of about 5 minutes - on sustainability theme. The contents of the presentation will include subjects such as the triple bottom line, the need to take into account the needs of future generation (Brundtland, 1987) as well as the Sustainable Development Goals (SDG). Each of the managers will then be invited to answer the following open question: “How would you solve the sustainability problem in your city?” They will be given two minutes to elaborate an answer. While they elaborate the answer, they will be monitored by electroencephalography (EEG).

The group will then move to a room where they will sit on chairs in a circle and have a SAM conversational meeting (Vasconcellos, 2015). They will be provided the necessary instructions. As is usual in SAM conversational meetings, there will be a coordinator and an observer. The role of the coordinator is to create and maintain a context of autonomy and safety in the conversational meeting, to foster participation, to inject as much requisite variety as possible in the discussion and to ask a question that takes the system out of balance. The role of the observer is to register as much as possible of what happens. In this situation, the managers will be

encouraged to share their ideas about sustainability, to look sustainability issues through the eyes of the other participants (Churchman, 1968) and also absent stakeholders, including future generations (Brundtland, 1987), thus exposing themselves to various aspects of sustainability

After being exposed to each other experiences and perspectives in the conversational meeting, each manager will be invited to answer the same question they have already answered before the meeting, i.e.: “How would you solve the sustainability problem in your city?” Again, they will be given two minutes to elaborate an answer, while monitored by EEG.

As a consequence of his exposure to the ideas of his colleagues, the answers of the managers are expected to be more elaborate. In other words, the conversational meeting enables systemic thinking, i.e., network thinking rather than linear thinking, so that the level of systemic understanding about the problem is increased, as described in Figure 1.

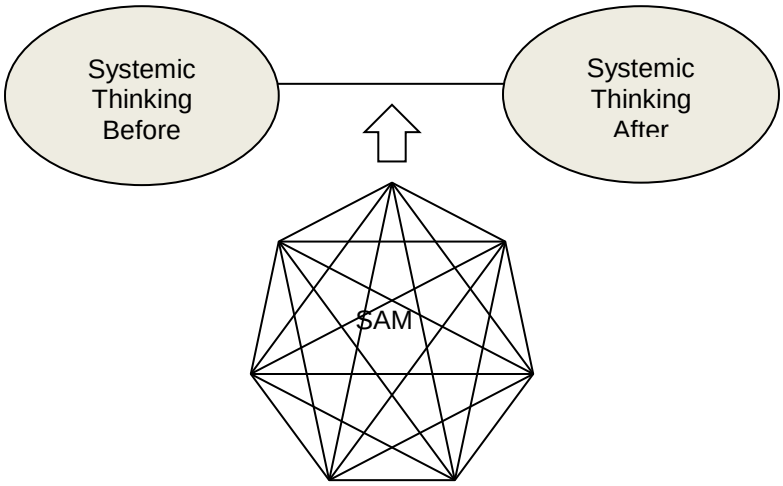

Figure 1 Systemic Assistance Methodology (SAM) and the differences in systemic thinking levels

We are assuming that the level of systemic thinking affects the level of consciousness about the sustainability problem. This regards a cognitive aspect of systemic thinking. The conversational meeting creates awareness about the many aspects involved in the problem situation and the brain tries to comprise the various elements in the problem situation, as well as the interrelations between them. A higher level of consciousness and a higher level of empathy lead to more effective solutions (figure 2).

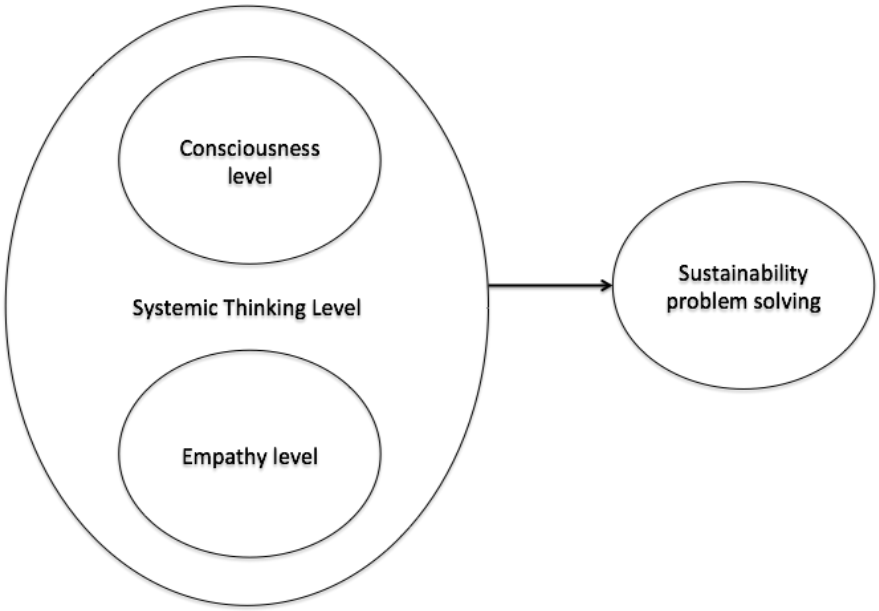

Figure 2 The relation of systemic thinking level and the sustainability problem solving

Two hypothesis arise from the of cause-effect of the mentioned constructs:

H1: The systemic thinking level is positively correlated with the consciousness level.

This hypothesis relates consciousness as measuring the concept of higher attention in the descending circuits results of EEG. Higher attention is analytical and "slow" like in Kahneman's

system (1973), it examines the options before giving a response, operates from "top-down" (descending system), situated in the prefrontal cortex. It is what differentiates the human being from other animal species, it is the possibility of thinking in the long term, pondering situations and choosing the one most appropriate to the circumstances. The descending circuits had full maturation after the ascending system, some hundreds of thousands of years from the evolutionary point of view of the human species. The higher attention of the respondent, the less the consciousness level.

We are also assuming that the level of systemic thinking affects the level of empathy with the situation and the stakeholders involved in it. This regards an affective aspect of systemic thinking. The conversational meeting creates involvement among the participants and allows their identification with the stakeholders' problems. The level of empathy is measured by the level of stress in the EEG, revealing the level of awareness and readiness to solve the problem.

H2: The systemic thinking level is positively correlated with the empathy level.

Empathy will be measured by the emotional strain (Stress) experienced by the respondent during an stimulus. EEG is a reliable tool reflecting upper cognitive functions and mental or psychological states. It is generally adopted that higher spectral activity is correlated with arousal, cognitive processing or emotional activity (Giannakakis et. al., (2015). The higher the stress level of an answer, the more emotionally involved is the respondent and the higher is his empathy for different stakeholders interests.

In summary, the conversational meeting, following MAS, enables systems thinking, which in turn is associated with both a higher level of consciousness and higher level of involvement (figure 3).

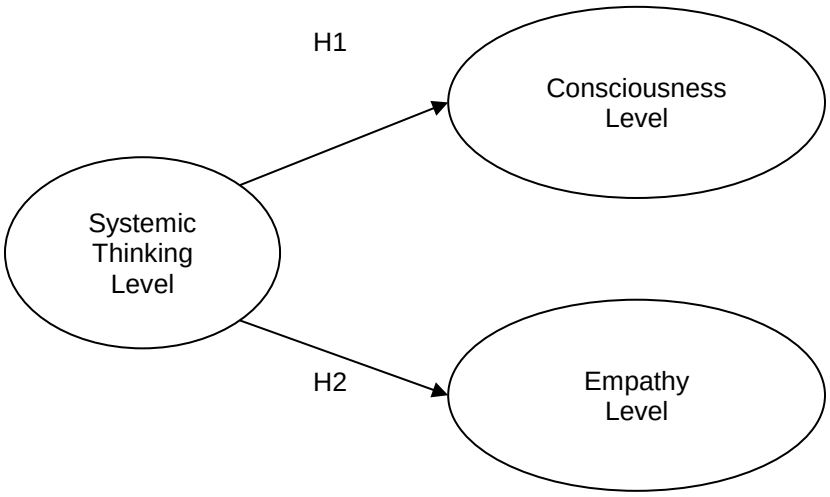

Figure 3 Systemic thinking and the consciousness and empathy levels

3.4 Measures

The level of systemic thinking will be measured by a discrete numerical variable that is calculated as the sum of the scores evaluated against three dimensions of systems thinking. Each dimension comprises a set of criteria. The first dimension (Table 1) is related to the number of sustainability aspects covered by the described solution. The second dimension (Table 2) is related to the number of different types of stakeholders benefited by the solution. The third dimension (Table 3) regards the nature of the system(s) implied in the description of a solution.

Table 1 Number of sustainability aspects

Score	Sustainability dimensions	Language used to describe the proposed solution(s)
0	Unsustainable	Spotty and temporary solution
1	Economic	Primarily economic aspects
1	Social	Includes social concerns
1	Ecological	Includes concerns with natural resources and the natural environment
1	Cultural	Includes cultural aspects

Table 2 Number of stakeholders of the system(s)

Score	Number of stakeholders	Language used to describe the proposed solution(s)
0	1	Just one type of stakeholder will benefit
1	2	Two distinct types of stakeholder will benefit
1	3	Three distinct types of stakeholder will benefit
1	4	Four distinct types of stakeholder will benefit
1	5+	Five or more distinct types of stakeholder will benefit

Table 3 Systems conceptual ideas

Score	Idea of systems	Language used to describe the proposed solution(s
0	Non-systemic	No evidence of systemic coherence.
1	Hard	Include ideas such as autonomy, integration, synergy, coordination, cooperation, adaptation to changes, strategy, vision
1	Soft	Include ideas such as learning, collective, cyclic, incremental, iterative, ongoing, trial and error
1	Emancipatory	Includes ideas such as participation, democracy, citizenship, emancipation, pluralism, representation of affect people that are not included in the discussion, including future generations …
1	Ethic	Include ideas such as self-denial and self-sacrifice on behalf of a greater good

The individual answers of the managers to the question: “How would you solve the sustainability problem in your city?”, before and after the conversational meeting, will be assessed against the three dimensions. The presence in the answer of a manager of a specific criterion in a particular dimension scores 1 point. The level of systemic thinking is calculated by summing up the scores in all of the dimensions:

$$ST = \frac{\text{Sustainability Scores} + \text{Stakeholders Scores} + \text{Systems Scores}}{12}$$

This expression yields a result between 0 and 1 (inclusive).

4. Discussion

In this paper, sustainability is considered a complex problem. Multiple stakeholders, different interests, simultaneously time planning and low objectivity in results construct a rich picture of global complexity challenges. On the other hand, public managers are expected to lead important environmental transformations and new social development in a certain locality. It is also known that the context of collaboration, construction and autonomy is propitious to systemic thinking development, enabling cognitive competencies that fulfill technical solutions.

Based on previous experience from the private market, we believe that systemic thinking can help public managers to perform better and effective decision-making towards sustainability issues. For that, we propose a research initiative, based on a field experiment, that measures systemic thinking to sustainability problem-solution.

The hypotheses are composed by taking the empathy or emotion involvement and the consciousness as antecedents to higher levels of systemic thinking. The more involved or conscious, more systemic will be the thinking of the respondents of the sample.

The experiment consists of a three-step process, starting from a stimulus and ending with the presentation of the same stimulus: a case of sustainability problem in the city where the public manager lives and works. Respondents will be submitted to an EEG while answering about the problem solution.

The manipulation procedure happens after the first session when respondents are invited to sit together and have a Systemic Assistance Methodology (SAM) (Vasconcellos, 2015) about the "problem-determined system" (PDS), problem-related to sustainability issues close to municipality scope. In this stage, a professional will be moderating the personal conversations in order to follow MAS rules. Finally, a third stage repeating first step proceedings is carried out, altering two different sources and kind of data.

To analyze the conversations session and the respective data we developed a specific scale, based in three dimension levels regarding the number of sustainability aspects covered by the described solution, the number of different types of stakeholders and the nature of the system(s) implied in the description of the solution. The sum of the scores on the scale will provide us the level of systemic thinking of the respondents, revealing if our intervention has any impact on improving public managers sustainability problem-solving.

Theory implication is the development of a novel method to measure the systemic thinking in individuals. No recent work has pointed to this exact direction however, Boyatzis (2006), Assaraf & Orion (2005) indicates the need for these cognitive and emotional aspects in social systems science. Using EEG to measure constructs as empathy and consciousness to complex problem-solving frameworks is also an innovative approach that can open a new research boundary, focused on analyzing individual cognitive competences as dynamic capabilities.

In a practical view, we expect that this work inspires public management and other institutions to open new boundaries to complex problem solutions, especially in critical ones as

sustainability. Specialist reports and technical frameworks can improve the decision-making process in learning context undoubtedly, but the evolutionary management theory is encompassing that emotional and social skills are individual dynamics capabilities capable of reinventing organizational trajectories and long-range strategies.

Our study has limitations. First, its external validity can be questioned, limiting the extent to which our findings can be generalized. Second, our study design measures used perceptual evaluations to systemic thinking instead of behavioral ones. Third, although our research design helps to shape the understanding of the individual decision, the group-level interaction processes are not investigated.

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